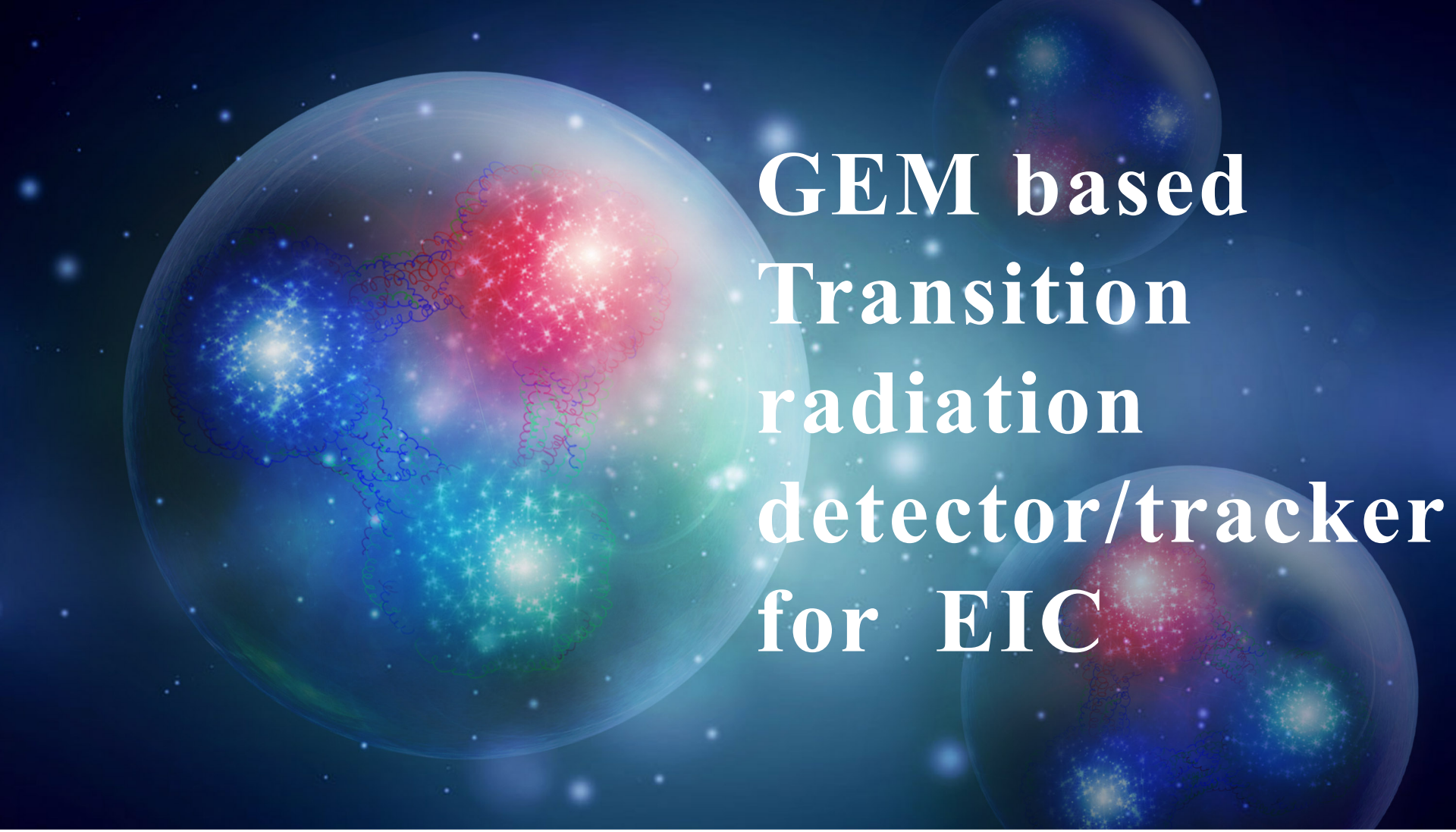


GEM based Transition radiation detector/tracker for EIC

Yulia Furletova (JLAB) on behalf of GEM-TRD/T working group

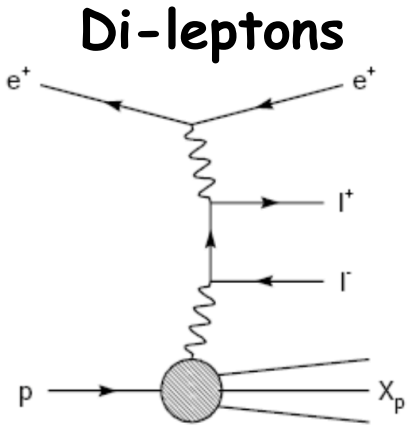
TEAM:

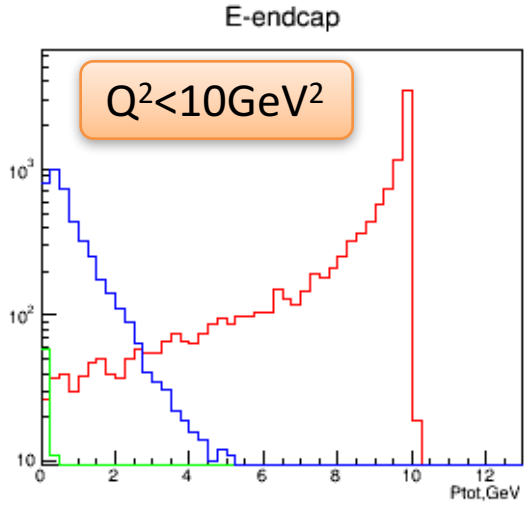
- TRD experts:
  - ✓ Yulia Furletova (EIC, Jefferson Lab)
  - ✓ Sergey Furletov (Hall-D, Jefferson Lab)
  - ✓ Lubomir Pentchev (Hall-D, Jefferson Lab)
- GEM experts:
  - ✓ Kondo Gnanvo (University of Virginia)
  - ✓ Nilanga K. Liyanage (University of Virginia)
  - ✓ Matt Posik (Temple University)
  - ✓ Bernd Surrow (Temple University)

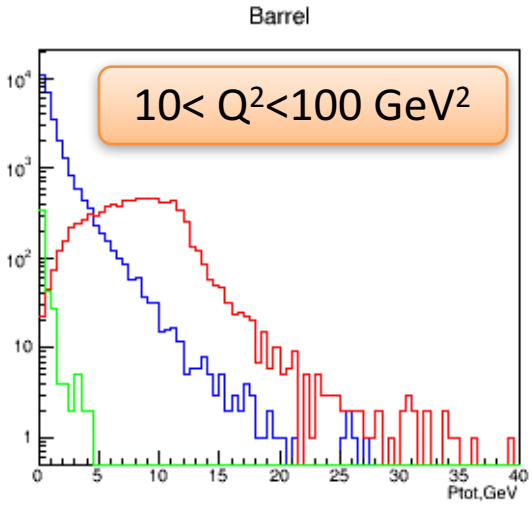
Electron Identification, Motivation

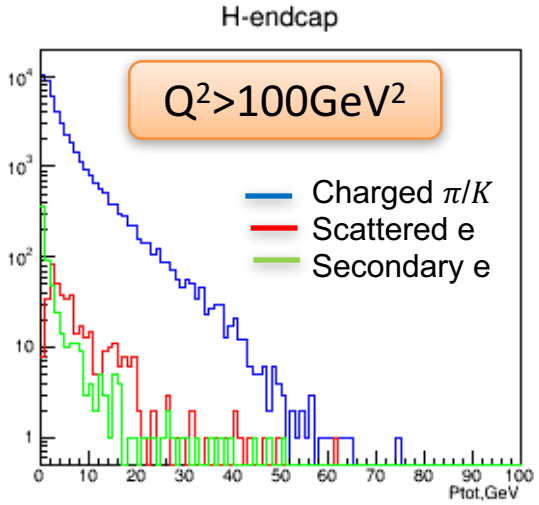
Physics at EIC:

- ✓ For rare physics, based on electron identification
- ✓Charmonium, light vector mesons (ρ,ω,φ)
- ✓Tetraquarks and Pentaquarks (and other XYZ states)
- ✓Open Charm physics via leptonic or semi-leptonic decays
- ✓Di-lepton production
- ✓ Scattered electron identification at Large-x, large-Q2

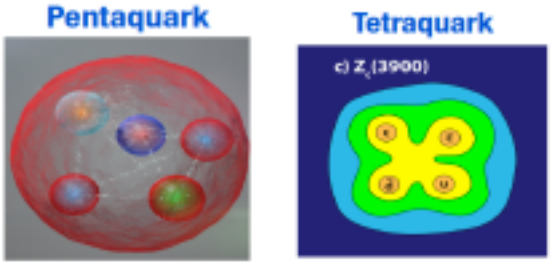


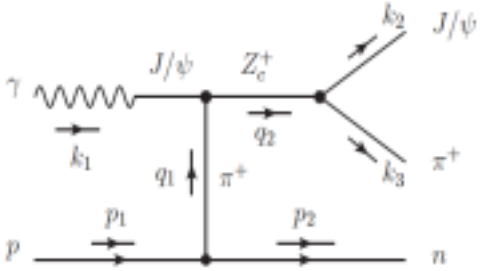




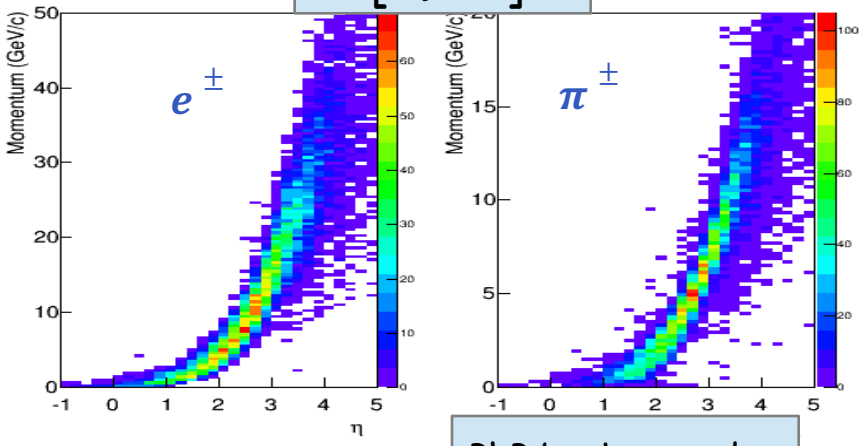


New XYZ states at EIC

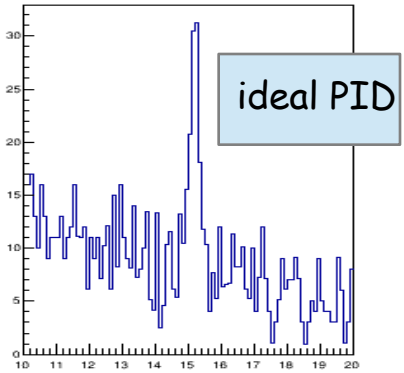




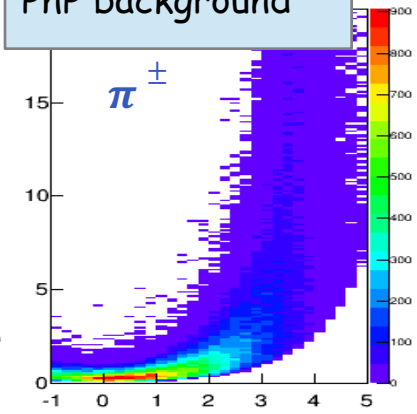
Zc[3900]

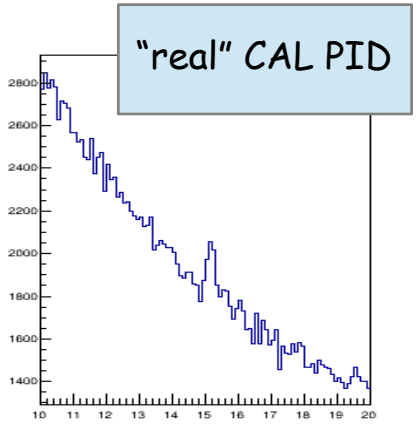


Zc[3900]
m^2 (e+e-π+)



PhP background





.Cross section:

σ(Zc[3900]) ~5 nb

σ(Q^2<1GeV) ~ 10^4 nb

.Decay e±,π+ boosted in proton beam direction

Excellent e/π PID in forward hadron region is needed for electron energy 1-100GeV

Hadron endcap detector

Environment:

- Background: High multiplicity heavy Ion collisions, large number of pions and Kaons in forward region.
- Large π^0 background.

Needs:

- 10^3-10^4 e/π rejection factor required over wide (1-100GeV) energy range in the forward region (EMCAL e/π rejection 50-100)
- High granularity tracker with low material budget, not very expensive=> GEM

Proposal:

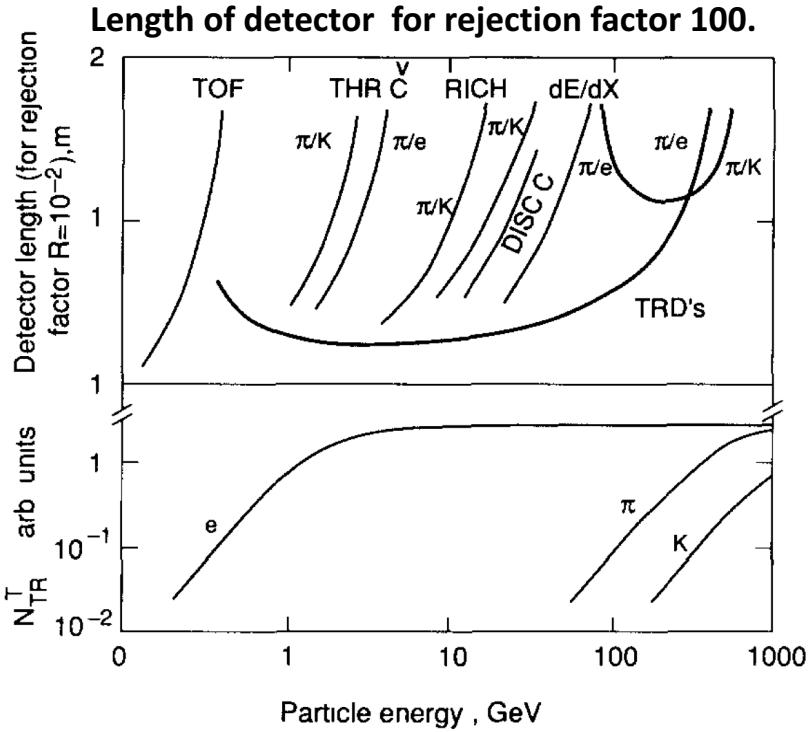
- Tracker combined with TRD/PID function: which could provide additional e/hadron rejection 10-100 and will cover energy range 1-100 GeV =>

GEM based transition radiation detector/tracker

GEM-TRD/T

Why transition radiation detector?

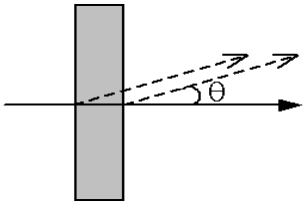
- TRD separate particles by their gamma factor
- e/π separation in high γ region (1-100 GeV) where all other methods are not working anymore.
- Provide high rejection factor for a small detector length in a wide range of a particle momentum.
- Identification of the charged particle "on the flight": without scattering, deceleration or absorption.



- Typically TRD is either combined with tracking detector (ATLAS TRT) or provide additional tracking information in the region between RICH and CAL(HERA-B).

Brief introduction to Transition Radiation

- Transition radiation is produced by a charged particles when they cross the interface of two media of different dielectric constants



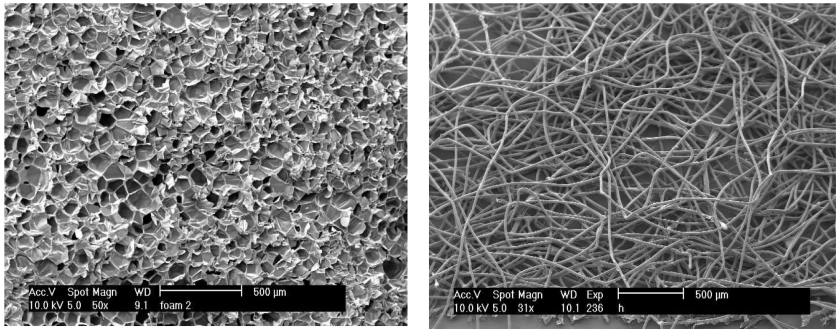
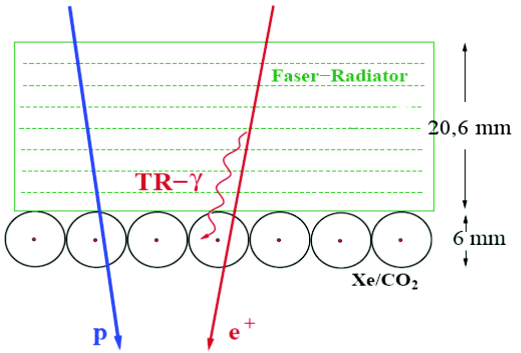
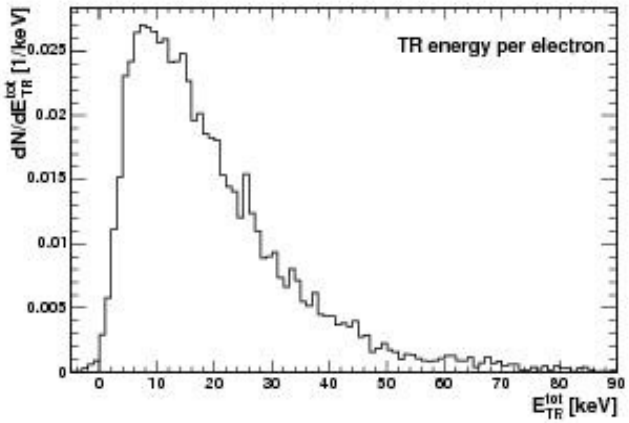
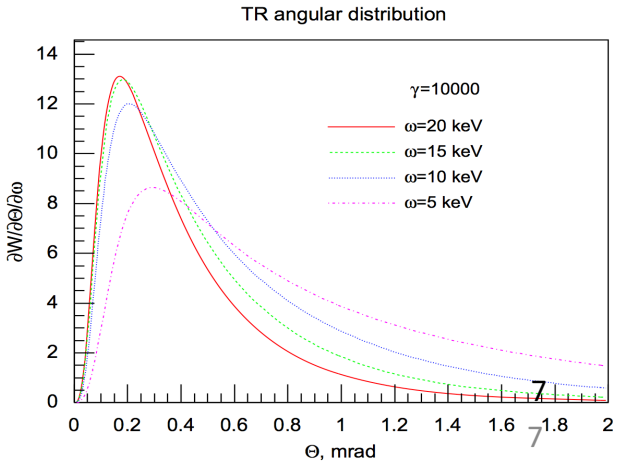


Figure 2: Electron microscope images of a polymethacrylimide foam (Rohacell HF71)(left) and a typical polypropylene fiber radiator (average diameter ≈ 25 μm) (right) [52].

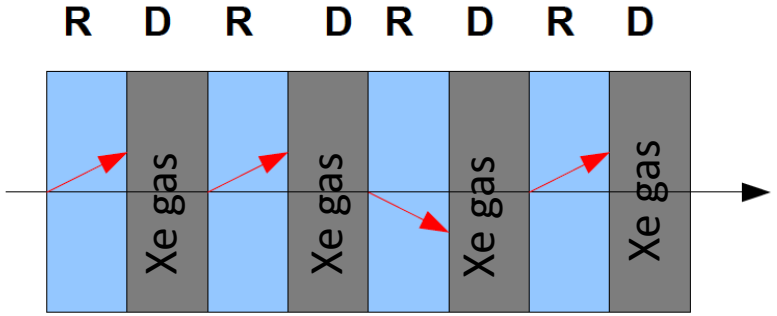




- the probability to emit one TR photon per boundary is of order α~1/137. Therefore multilayer dielectric radiators are used to increase the transition radiation yield, typically few hundreds of mylar foils.
- TR in X-ray region is extremely forward peaked within an angle of 1/γ
- Energy of TR photons are in X-ray region (2 - 40 keV)
- Total TR Energy ETR is proportional to the γ factor of the charged particle

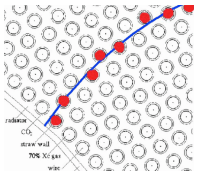


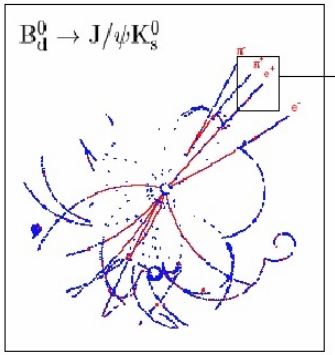
How easy to detect Transition Radiation ?

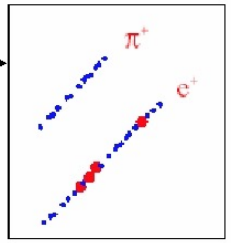


- Stack of radiators and detectors (sandwich)
- For "classical" TRD (straws, MWPC) gas is needed for better absorption of TR photons: high Z required => Xenon gas (Z=54)
- TRDs are not "hadron-blind" ! they see all charged particles dE/dx
- Several methods exist to identify TR photons on the top of dE/dx:
  (TR photons (5-30 keV) over a dE/dX background in Xe gas (2-3 keV)).

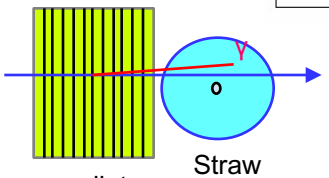
ATLAS TRT

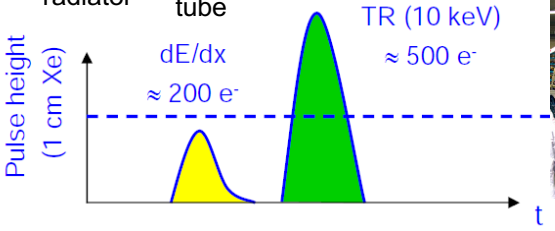


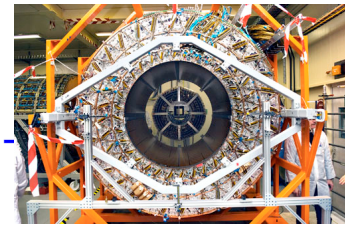




Simulated event, illustration of clusters from eletron/positron and pion hits – small blue dots are ionizing hits, large red dots are TR hits



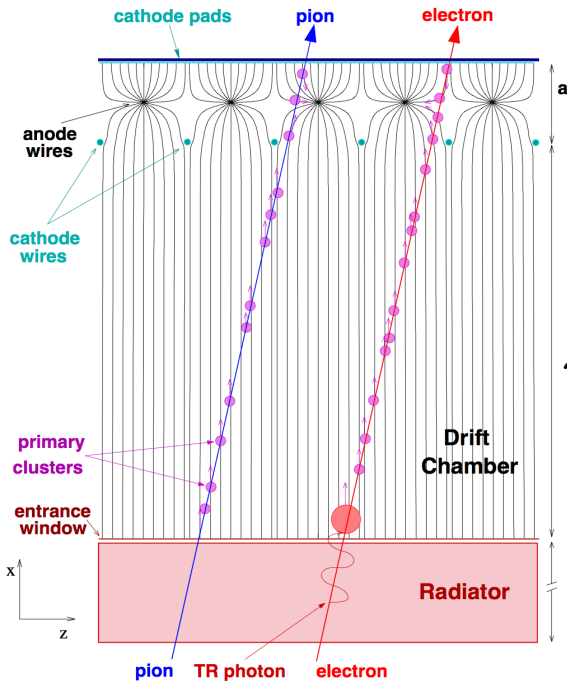




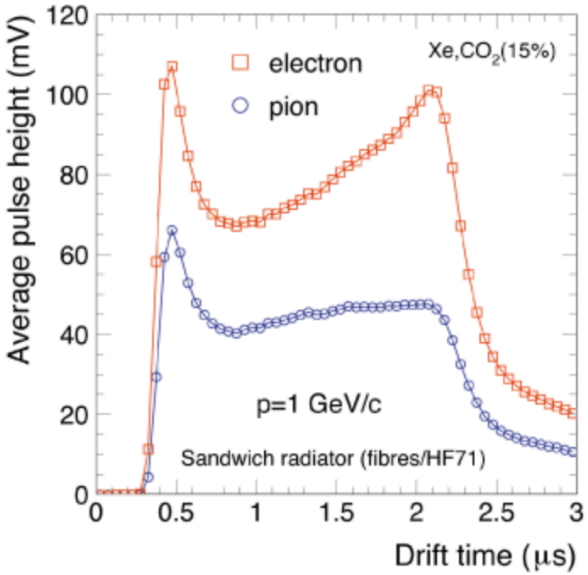
- **Discrimination by threshold** (ATLAS)
- **Average pulse height along adjacent pads (or along a track)** (ALICE) => (next slide)

TR detection in MWPC, Silicon

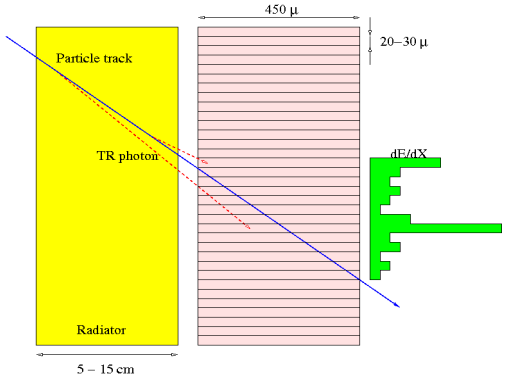
At MWPC:
For electrons - significant increase in the average pulse height at later drift times, due to the absorption of the transition radiation near the entrance of the drift chamber.

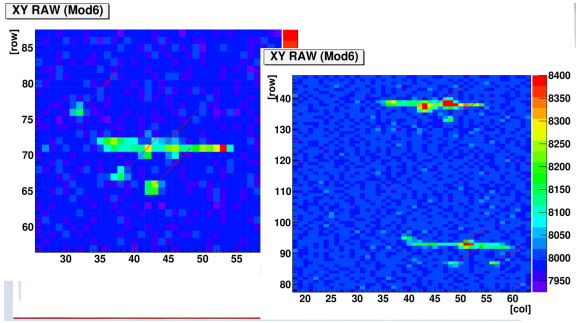


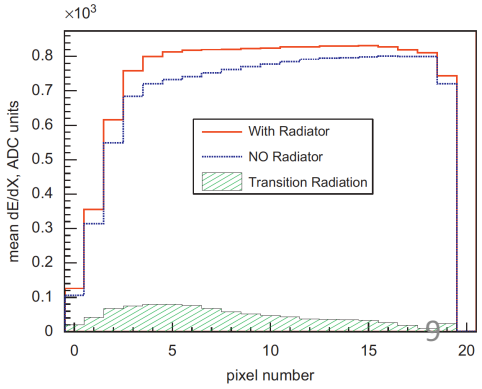
ALICE MWPC - TRD



Silicon DEPFET-pixels TRD

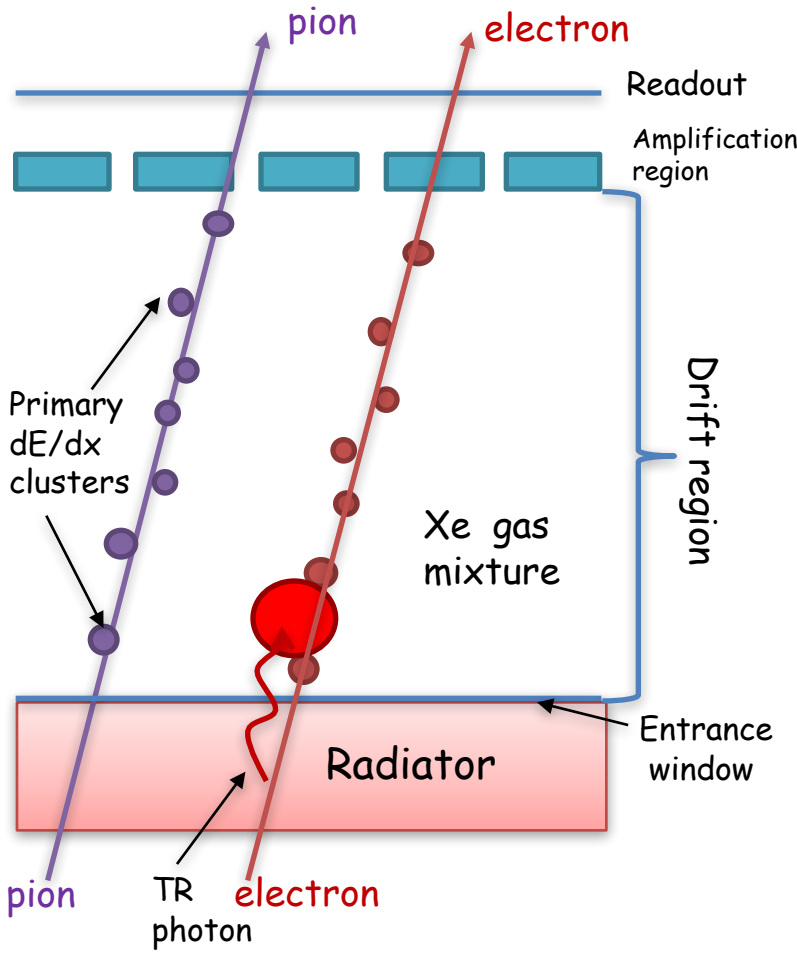






GEM as Transition Radiation detector and tracker for EIC

- High resolution tracker.
- Low material budget detector
- How to convert GEM tracker to TRD:
  - ✓ Change gas mixture from Argon to Xenon (TRD uses a heavy gas for efficient absorption of X-rays)
  - ✓ Increase drift region up to 2-3 cm (for the same reason).
  - ✓ Add a radiator in the front of each chamber (radiator thickness ~5-10cm)
  - ✓ Number of layers depends on needs: Single layer could provide e/pi rejection at level of 10 with 90% electron efficiency.



Radiators

- The theory of transition radiation predicts that the best radiator is a stack of regular foils:

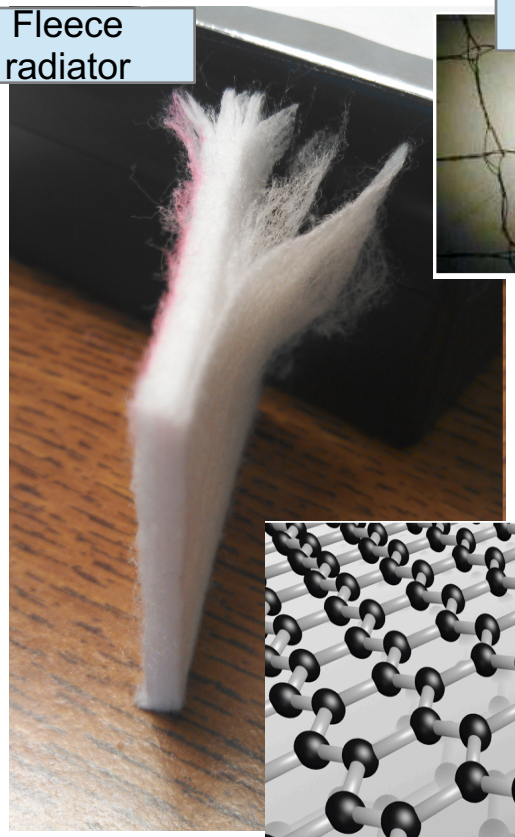
  20-30μ mylar foils and 200-300μ air gap.

- ATLAS uses foils and spacer between foils to provide air gap.
- ZEUS and many other experiments used fleece radiator
- Proposals to use Graphene radiator:

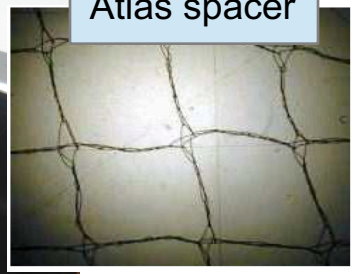
  "Measuring the Lorentz factors of energetic particles with transition radiation", M.Cherry, 10.1016/j.nima.2012.05.008

- Boron Nitride Nanotubes (BNNT company)

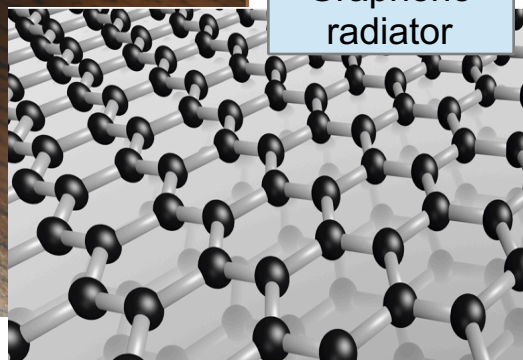
Fleece radiator

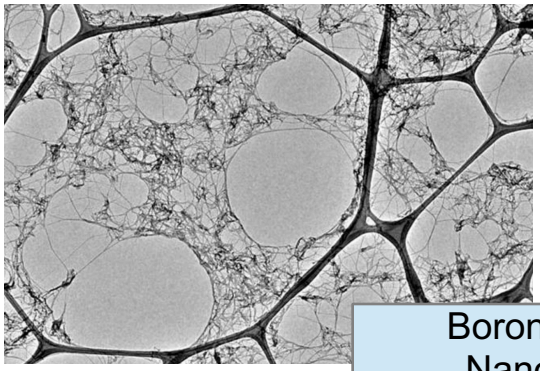


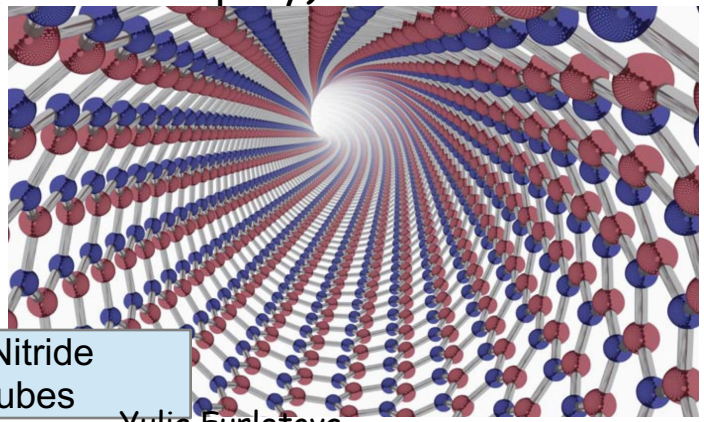
Atlas spacer



Graphene radiator



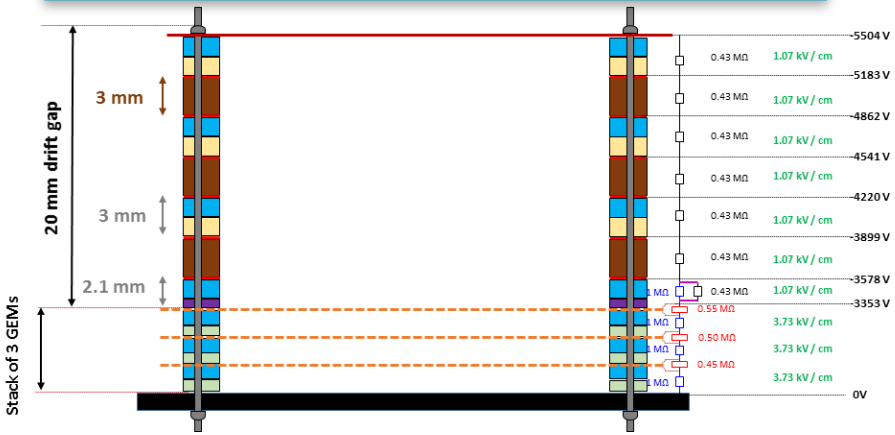




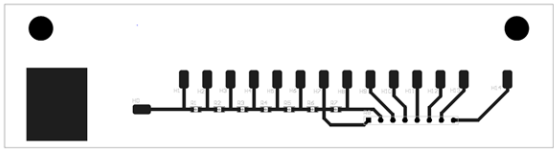
Boron Nitride Nanotubes

GEM -TRD/T prototype @ UVA

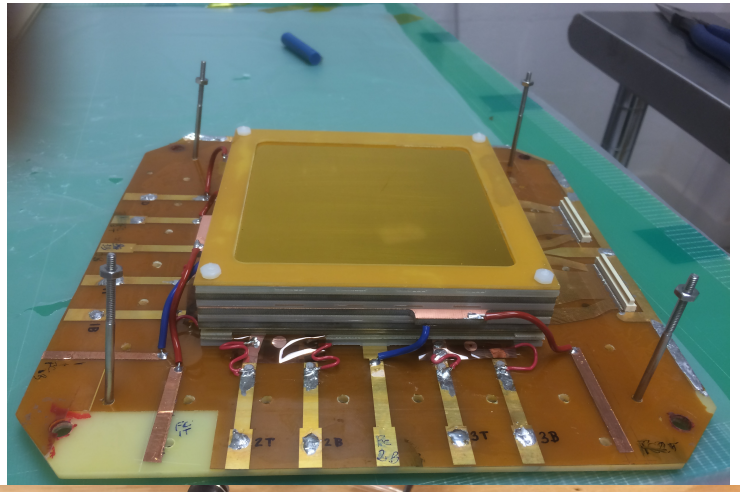
GEM-TRD/T cross section, 20mm drift volume



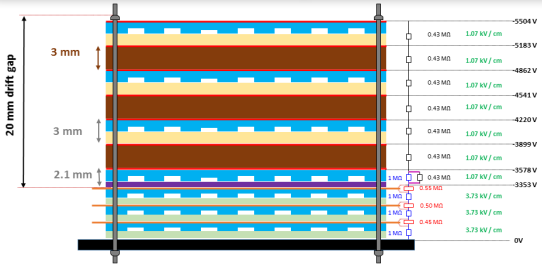
Drawing for the resistive divider



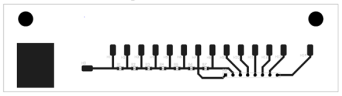
HV 5504 V,
Resistive Divider = 7.404 MΩ,
Max current = 747.3 μA



Walls cross section(for field correction)



Drawing for the resistive divider



HV 5504 V,
Resistive Divider = 7.404 MΩ,
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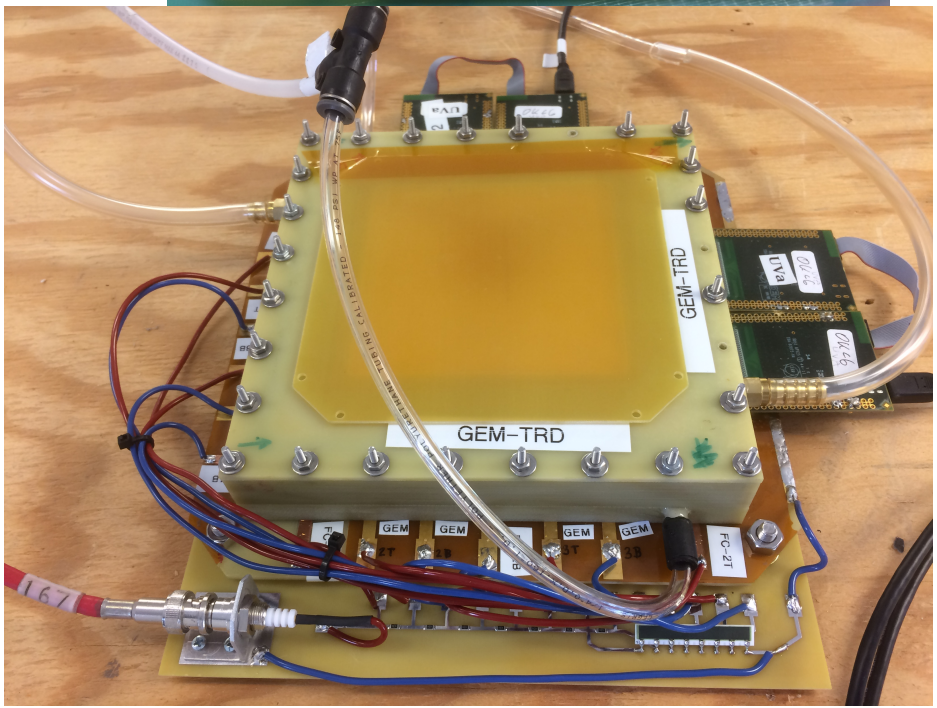
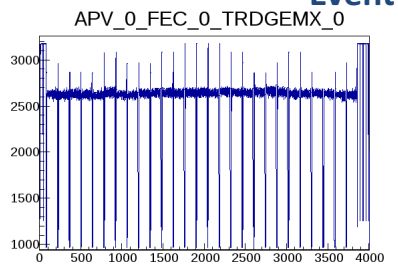
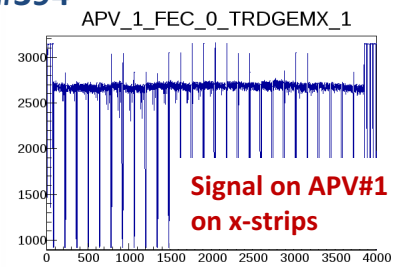
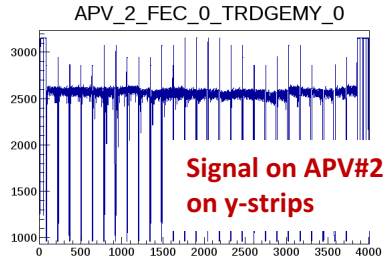


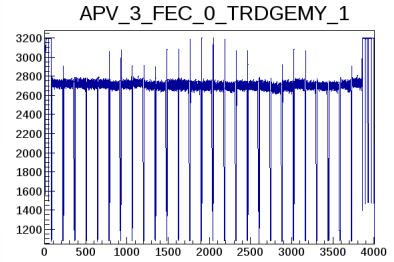
Cosmic run with GEM-TRD/T prototype @ UVA

Event #394

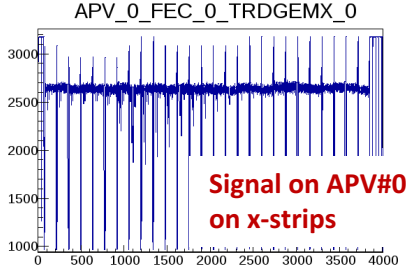


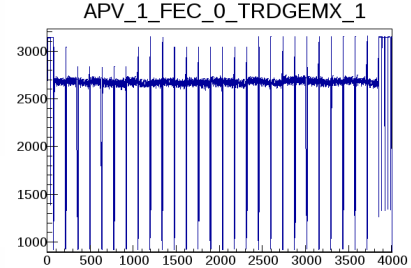


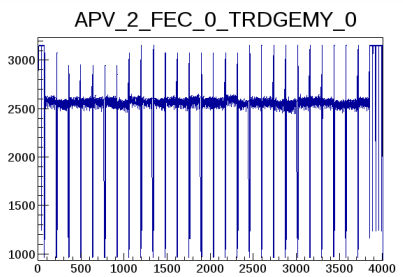


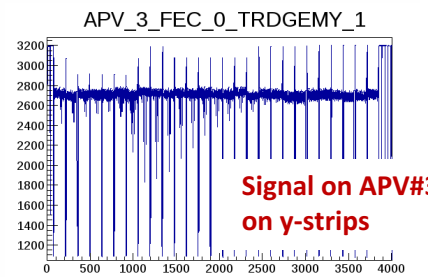


Event #911



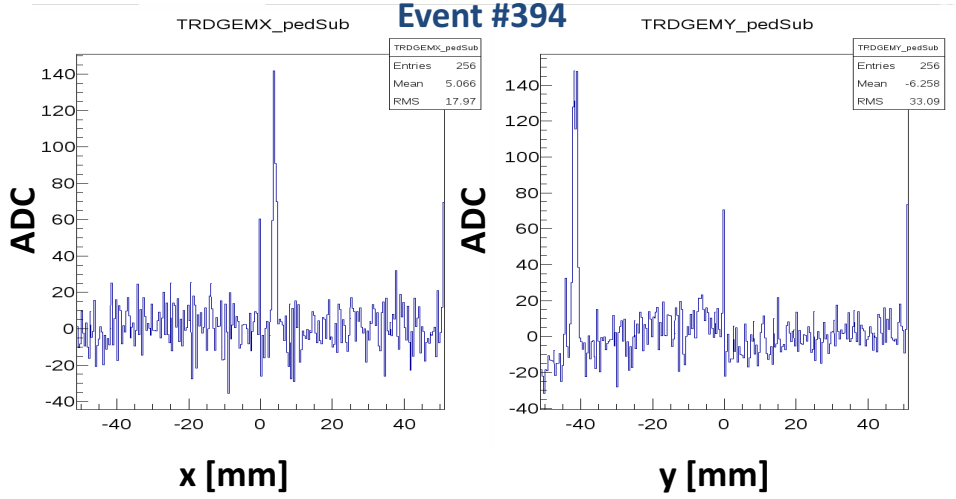




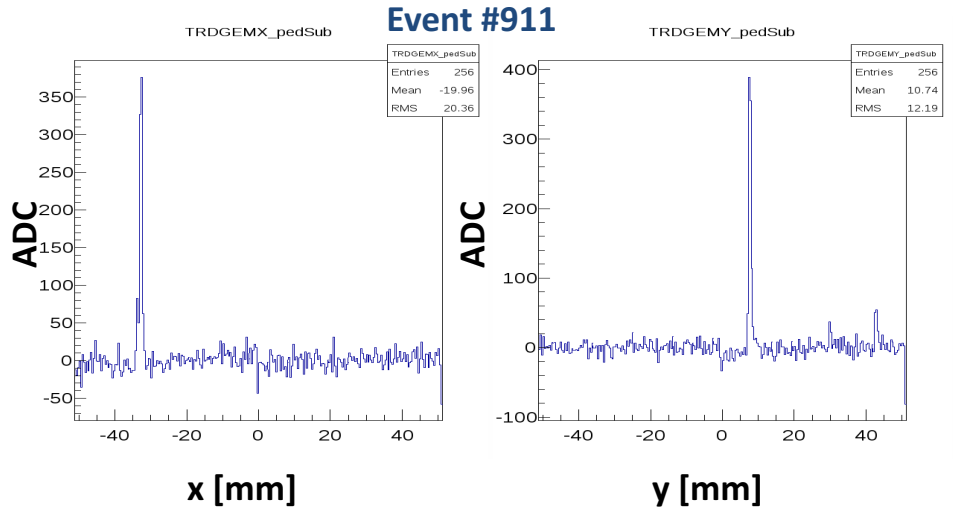


Decoded hits in x and y direction of TRDGEM

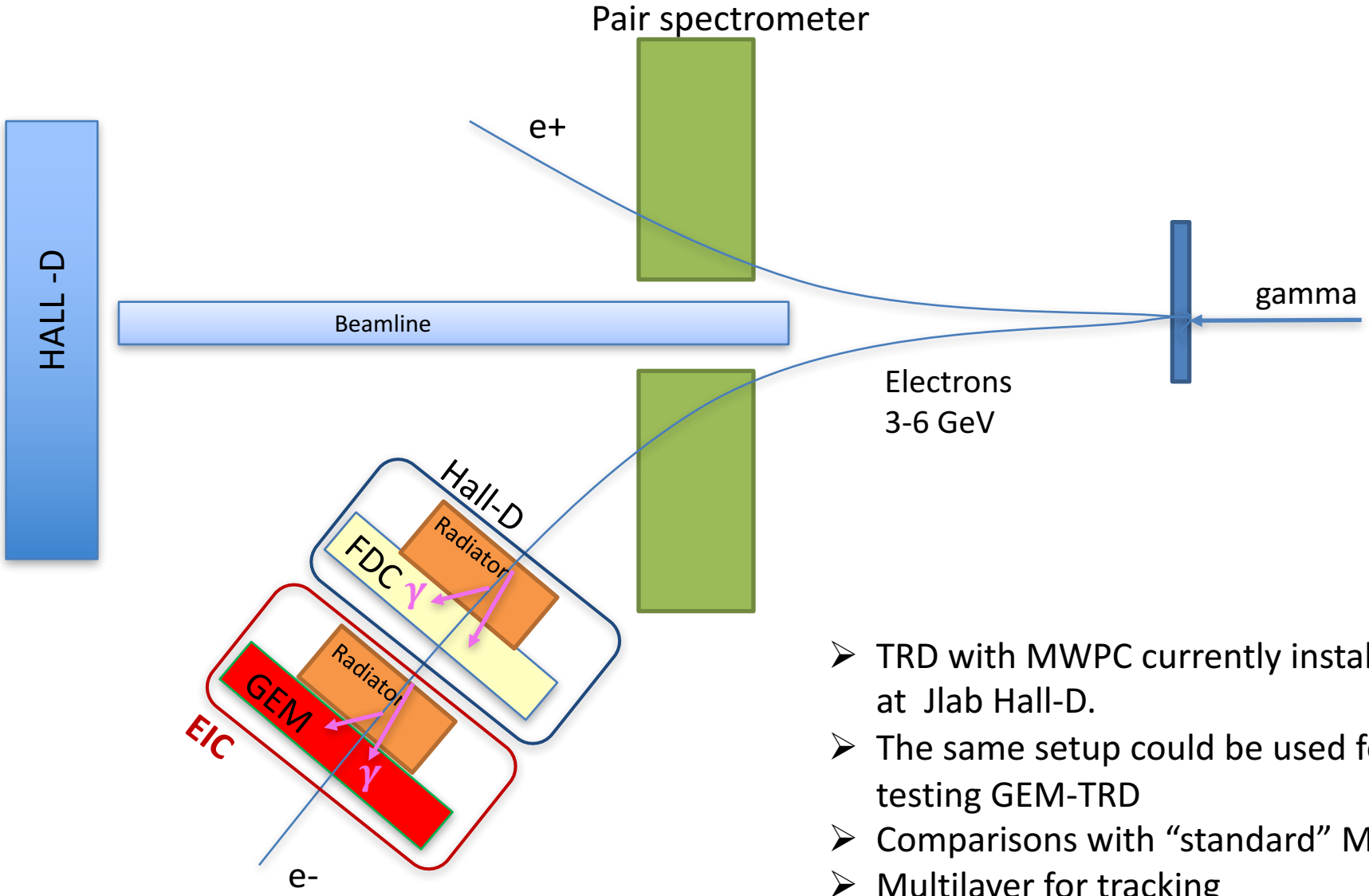
Event #394



Event #911



Test Setup at JLAB HALL-D



- TRD with MWPC currently installed at Jlab Hall-D.
- The same setup could be used for testing GEM-TRD
- Comparisons with “standard” MWPC
- Multilayer for tracking

PROPOSAL FOR R&D

- GEANT4 simulation of TRD setup with GEM detector
  - Estimate e/pi rejection factor for different configurations: layers, gases, electron efficiencies…
- Using the existing facility at JLAB Hall-D perform a test with "known" radiators (ATLAS, ZEUS, etc.) – "proof of principle"
- R&D and tests of other TR-radiators
  - nano-technological radiators from BNNT (BNNT company provides a test samples)
- Test "existing" GEM front-end electronics and readout system for TRD purpose.
- Test different Xe-gas mixtures: drift time, voltages and gas-gain, adjustments.

PROPOSAL FOR R&D

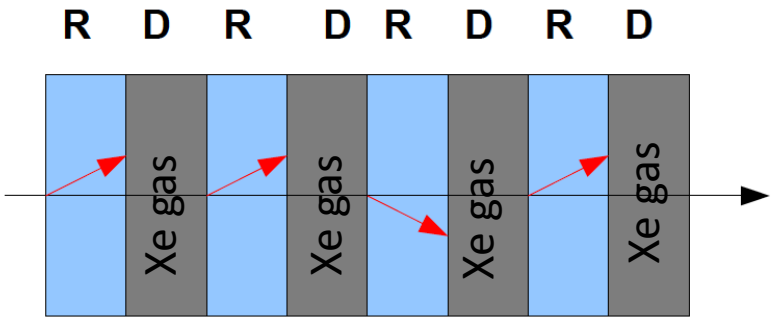
Needs:

- Xe gas ($10 - $20 per liter)
- Material/equipment :
  - GEM-TRD/T prototype modifications
  - Radiators
  - Mechanical boxes/support
  - Gas system: tubes/pipes, rotameters, pressure controls, CO_2 control (purification system is not needed for tests at the moment)
  - DAQ-PC with disk storage
- Travel to the testbeam

Thank you!

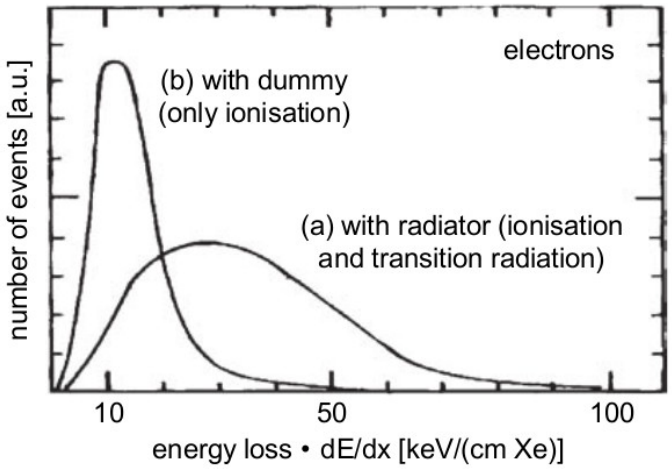
Backup

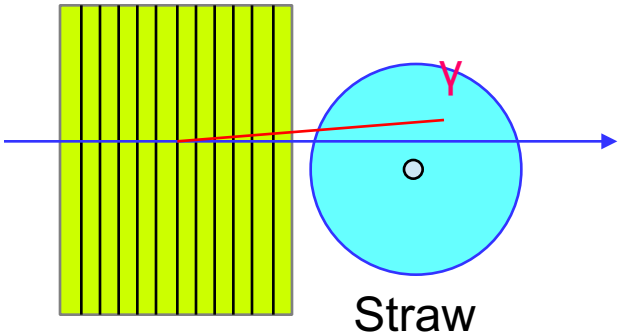
Xe –gas detectors

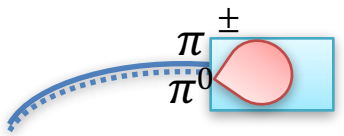


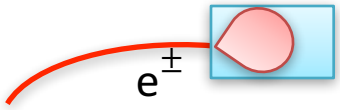
- Stack of radiators and detectors (sandwich)
- For "classical" TRD (straw, MWPC) gas is needed for better absorption of TR photons: high Z required => Xenon gas (Z=54)

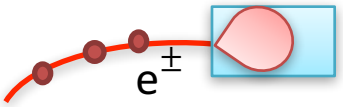
- TRDs are not "hadron-blind" ! they see all charged particles dE/dx:
  - Intrinsic problem: detector "sees" both TR & dE/dx
  - TR photons (5-30 keV) over a dE/dX background (2-3 keV).

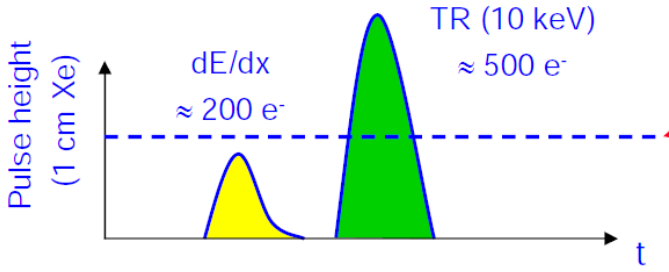








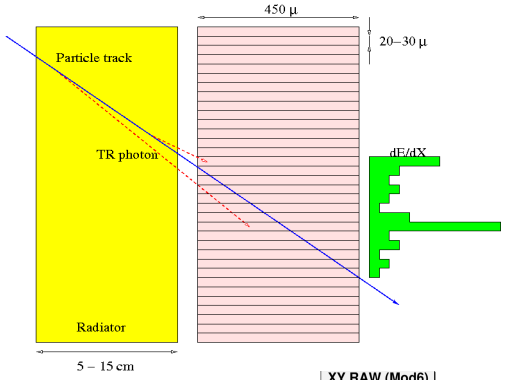


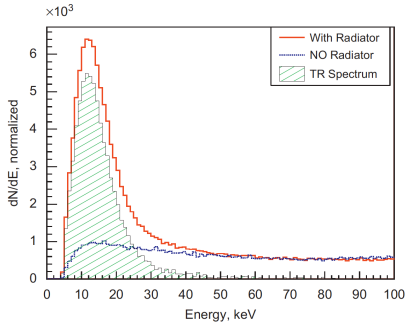


discrimination by threshold

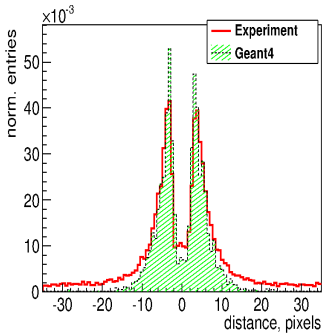
Silicon pixel TRD

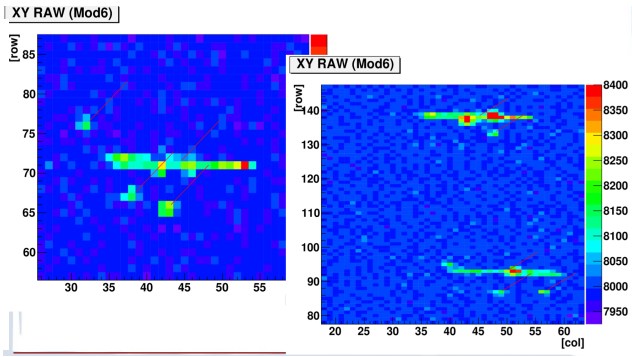
Problem: A huge dE/dX of particles in 300-700μm of silicon - about 100-300keV (TR photons 4-40 keV).





- **DEPFET silicon pixel detector**
  - Low noise, high S/N with 450 μm thick fully depleted bulk(sensitive area), pixel size – 20x20μm^2 .
  - TR photons are clearly visible and separated from track by a few pixels!

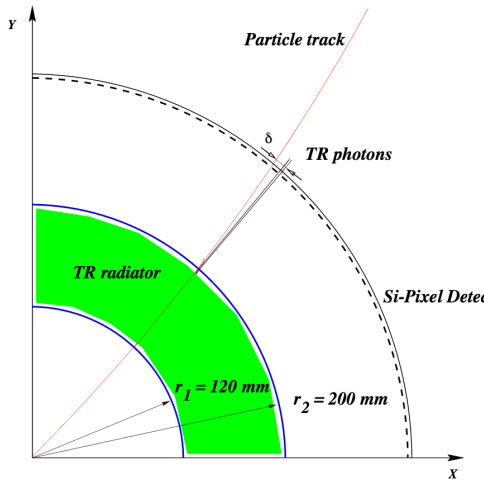




"New transition radiation detection technique based on DEPFET silicon pixel matrices", J.Furletova, S. Furletov, NIM-A 2010, http://dx.doi.org/10.1016/j.nima.2010.06.342
"Geant4 simulation of transition radiation detector based on DEPFET silicon pixel matrices", J. Furletova,S. Furletov, DOI: 10.1016/j.nima.2012.05.009

- **Separation of TR and dE/dX in different pixels in magnetic field**

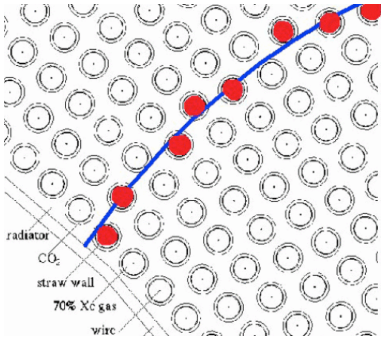
2000 B. Dolgoshein proposed a design for ILC/TESLA detector (see proposal LC-DET-2000-038)

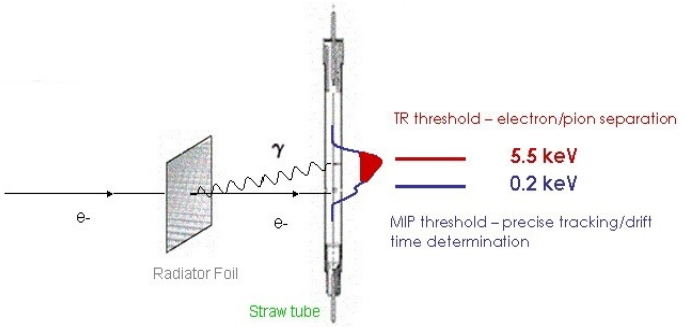


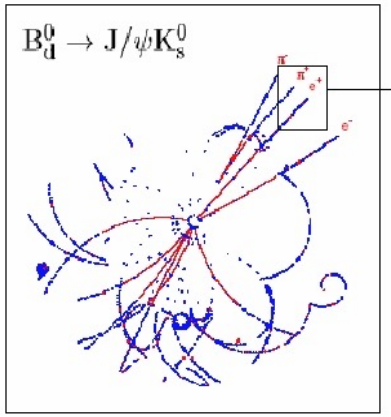
20

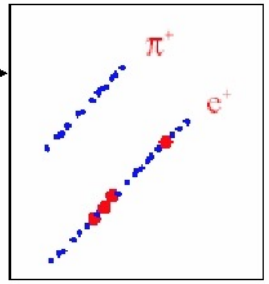
TRD with Straws

- The classical TRD is based on gaseous detectors filled with Xenon gas mixture to efficiently absorb transition radiation photons.
- Cluster discrimination by threshold method used to discriminate TR photons (5-30 keV) over a dE/dX background (2-3 keV).



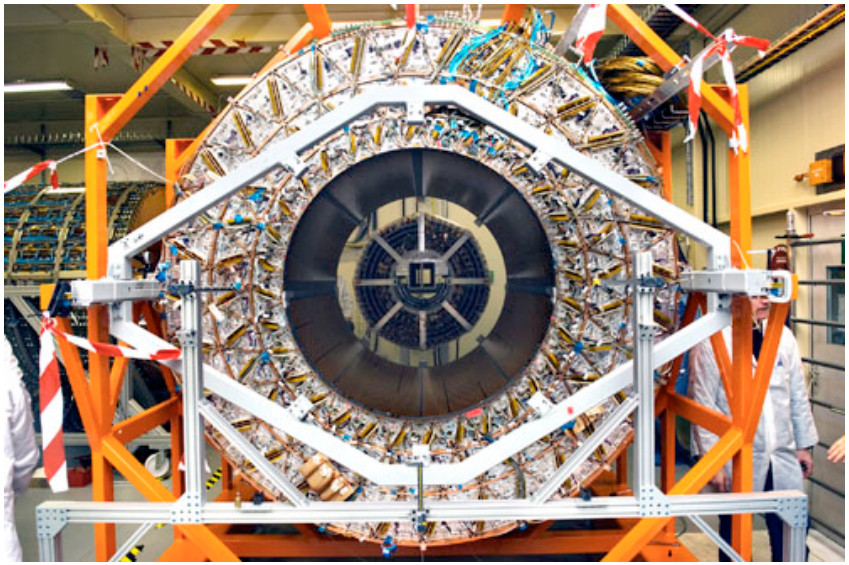






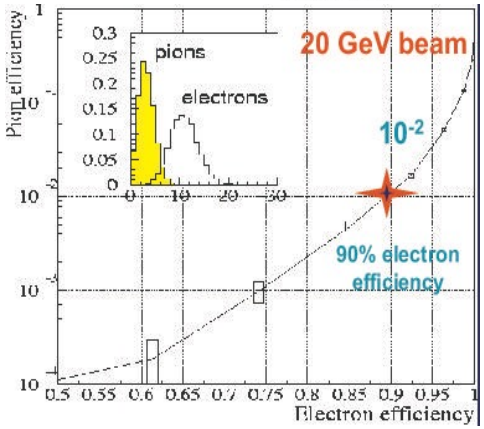
Simulated event, illustration of clusters from eletron/positron and pion hits – small blue dots are ionizing hits, large red dots are TR hits

ATLAS TRT Barrel



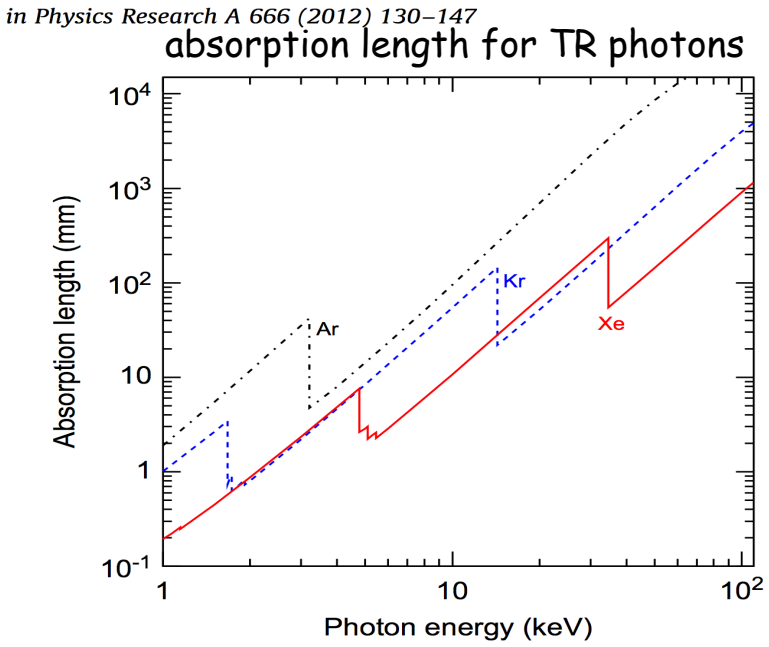
ATLAS TRT

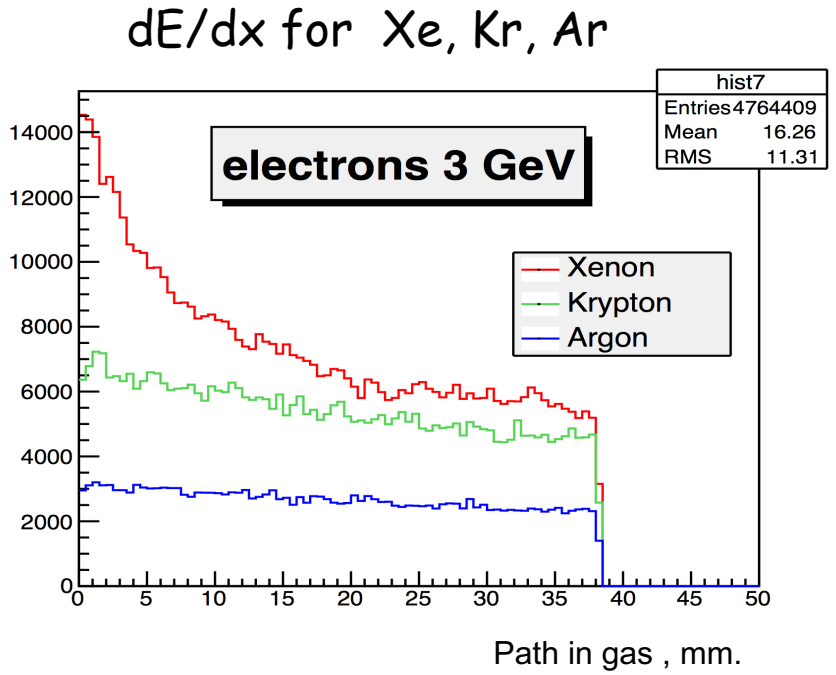
-Straw tubes (proportional chambers) 4mm diameter and up to 144 cm long
-drift time ~50ns
-track reconstruction ~150-200 μm
-e/pi rejection factor ~100.



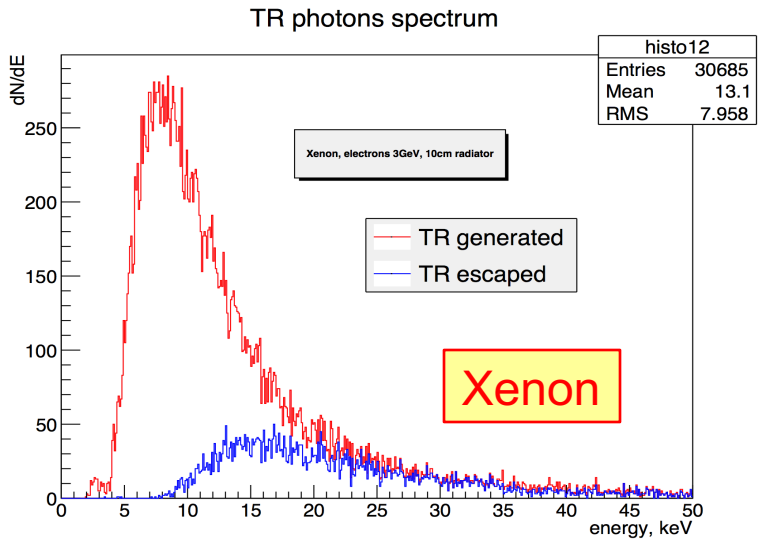
Xe alternative?

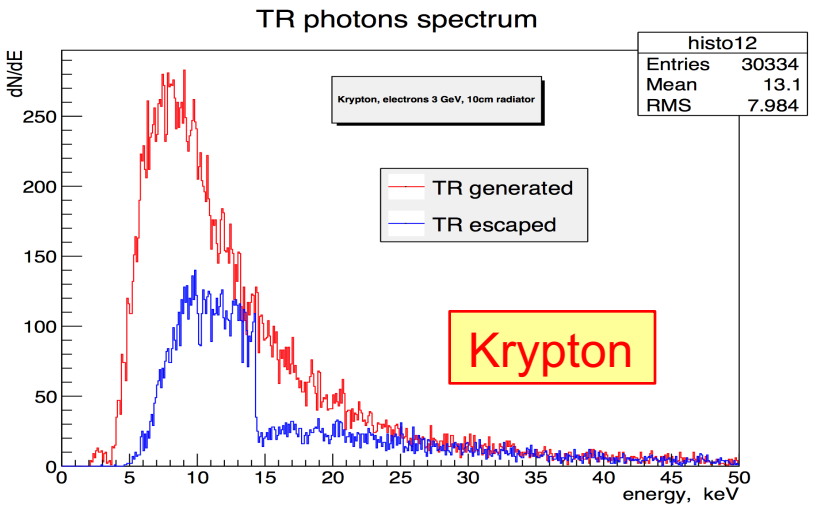
- Xenon price is prohibitive to use it just like an Argon: $15 - $20 per liter.
  - needed gas purification system.
- Is there any alternative to Xenon ? : Krypton ? Argon ?

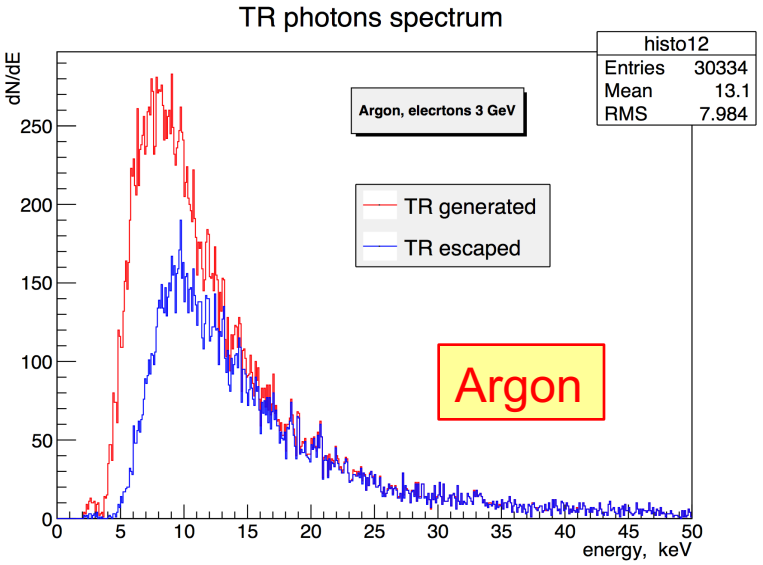


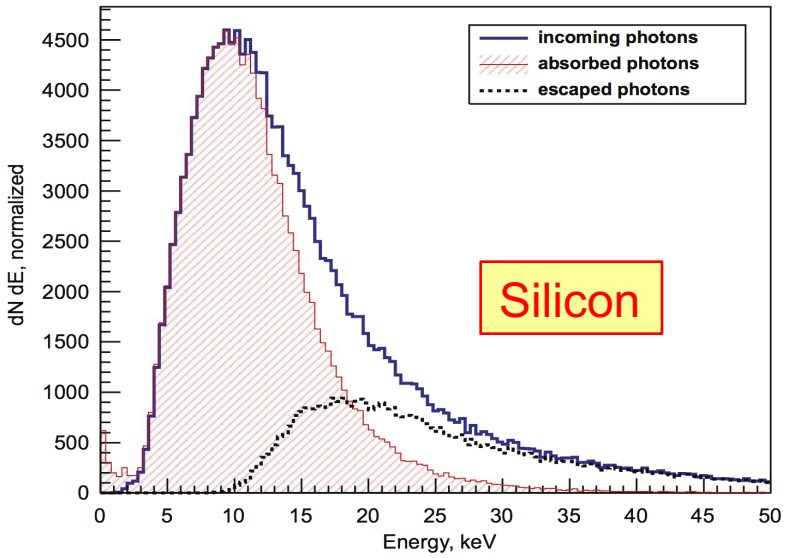


TR absorbtion

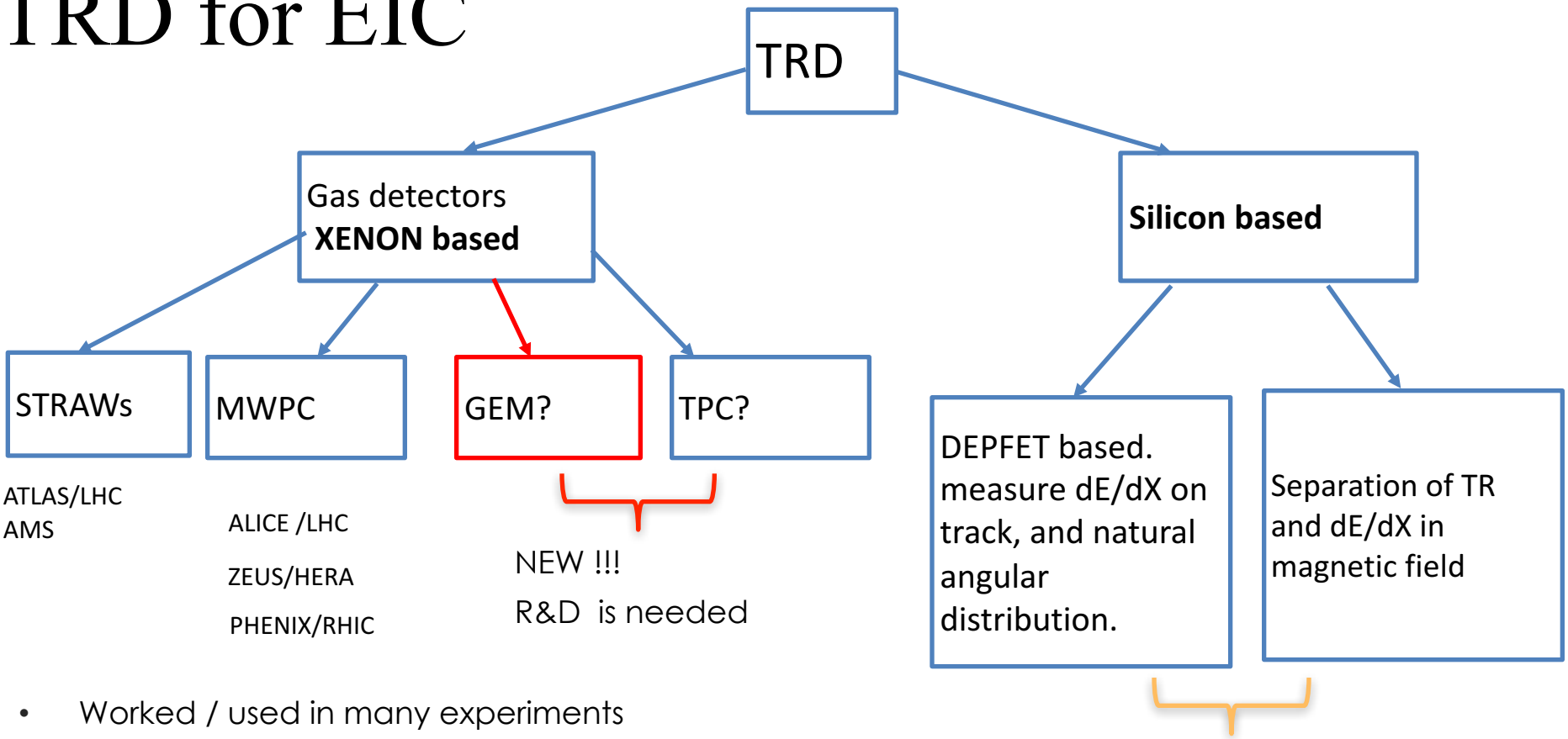








TRD for EIC



- Worked / used in many experiments
- Could cover large area.
- X/X0 ~0.2 % for 4cm of Xe
- X/X0 ~1.5% for 10 cm of radiator
- Problem: Xenon is very expensive => gas purification system is needed.

- NEW !!! R&D is needed
- X/X0 ~1.5% for 600μm of Silicon
- X/X0 ~1.5% for 10cm of radiator
- Problem: price for DEPFET detector => not for large areas => may be for Vertex?